

Rethinking Distal Thoracic Aortic Landing Zones

Dissecting the role of anatomy, devices, and techniques for preventing distal landing zone failure.

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When thoracic and thoracoabdominal aortic pathology pushes the limits of currently available thoracic endovascular aortic repair (TEVAR) technology, we need to enhance our techniques to repair increasingly complex anatomy that, if treated by open surgery, is associated with significant morbidity and mortality.¹ Compromised distal landing zones have been implicated in late type Ib endoleaks, stent migration, and failure to seal a false lumen in the case of dissection. Furthermore, as with abdominal aortic pathology after endovascular repair, more attention has been paid to anatomic changes after TEVAR and how these may relate to loss of seal. As the late progression of distal landing zone failure has become better understood, the development of adjuncts to allow extension of the distal seal zone has been more widely used.²⁻⁴

UNDERSTANDING DISTAL LANDING ZONE ANATOMY

The qualifications for an ideal distal landing zone are somewhat different depending on the thoracic pathology being addressed. For aneurysmal disease, the goal is exclusion of the sac with adequate coverage into normal aorta. In contrast, the optimal distal landing zone in aortic dissections seals into nondissected aortic tissue and covers all entry tears, promoting false lumen thrombosis and optimal aortic remodeling potential.⁵ Most commercially available TEVAR devices require a distal landing zone of 20 to 30 mm, ideally into a relatively straight segment of healthy aorta.

The accuracy of graft deployment in the distal seal zone is much more dubious than the proximal, largely related to the deployment devices. When using the definition of precise landing as ≤ 5 mm from the target vessel, only about 17% of grafts will land as intended. Although they most commonly land short, in a small subset they can partially or completely cover a branch vessel.⁴ An in vitro study illustrated the “stent graft jump phenomenon,” wherein as the graft exits the deployment

device the law of conserving momentum acts upon the device, simultaneously pushing the graft toward the aortic wall and away from the deployment sheath.⁶ This diminished ability to land the distal extent of the graft with the same accuracy as the proximal can lead to compromised seal and technical failure both in the short and long term, particularly in those patients with marginal anatomy.

Even with accurate TEVAR deployment and a successful initial result, late anatomic changes in the distal landing zone can compromise a once adequate seal. It has been recognized in the abdominal aortic literature that ongoing aortic neck dilation after initial endovascular aneurysm repair (EVAR) placement can occur and lead to late developments of type I endoleaks.⁷ When we turn that lens toward the thoracic aortic aneurysmal patient population, several anatomic characteristics have borne out as higher risk for potential degeneration that can compromise the distal seal. In the aneurysmal population, a compromised distal seal zone includes patients with aortic diameters > 35 mm, cross-sectional thrombus $\geq 50\%$, circumferential mural calcification $\geq 25\%$, or a tortuosity index (measured by dividing aortic length by geometric length) in the 10 cm above the celiac axis of > 1.1 .⁸ Case planning in patients with these anatomic features may benefit from additional adjunctive maneuvers either at the time of initial surgery or in follow-up to help obtain and maintain a seal.

As the goal of distal seal in the dissection patient is somewhat different from the aneurysmal patient, so are the anatomic characteristics that may deem the seal zone high risk. Ideally, the aortic stent graft will land in nondissected aorta. Unfortunately, this is not possible in the up to 80% of patients who see their dissection extend into the abdominal aorta, and this fact remains the greatest risk factor for later anatomic changes resulting in loss of seal. Avoidance of aggressive oversizing is key in these patients to decrease the incidence of stent graft–induced new entry (SINE), which can lead to continued perfusion

of the false lumen. Although not often seen at the time of initial surgery, SINE can occur later in up to 16% of patients. Moreover, in one-fifth of patients, the aorta in the distal seal zone dilates to the nominal diameter of the graft over time.^{8,9} Because the aortic diameter is known to immediately increase by approximately 20% at the time of dissection anyway,¹⁰ rather than oversizing, it is prudent to consider the predissection diameter when planning for cases. Although this may not obliterate the false lumen, it may potentially decrease the chance of SINE with resultant reperfusion of the false lumen as well as further aortic diameter degeneration.

ADJUNCTIVE MANEUVERS FOR PRIMARY SEAL

It has been established in the abdominal aortic aneurysm literature that with endosuture reinforcement of the seal zone, neck dilation may not occur.¹¹ The use of endoanchors during EVAR has been shown to be safe and protective against stent migration and further neck dilation and thus minimize the occurrence of type Ia endoleaks, particularly in wide or angulated necks, which can expand the use of standard stent grafts and mitigate the risks associated with more complex endovascular or open repairs. The experience with endoanchor use in the thoracic aorta is more limited, although much of the technical failure reported is related to use in the proximal landing zone of TEVARs where the anatomy is different and the learning curve is higher than in the descending seal zone that more closely mimics the abdominal aorta where surgeons tend to have more experience with this technology. Many series report the use of endoanchors at both the proximal and distal landing zones. Some early experience showed a similar trend toward decreased incidences of both aortic dilation and stent graft migration when used with TEVAR.¹²

The only device currently available in the United States is the Heli-FX EndoAnchor system (Medtronic), which has been determined to be compatible with Medtronic, Cook Medical, and Gore & Associates thoracic stent grafts. The delivery device comes in a working length of either 82 or 114 cm to reach most aortic seal zones, and separate guides with varying deflected tip lengths that should be sized based on the aortic diameter are used to steer the device. Because the endoanchor requires purchase with the adventitia to be effective and in fact may not deploy correctly or fracture if improperly used, it is not recommended for use in seal zones that have significant thrombus or calcification, making this adjunctive technique more useful in the wide or angulated high-risk distal seal zone.

EXTENSION INTO THE VISCERAL SEGMENT

When treating aneurysmal disease, there will be patients based on either aortic size at the time of the initial operation or from degeneration over time who will benefit from the extension of the distal seal into the visceral segment. It has been shown that celiac coverage in the setting of adequate visceral collateralization to extend distal landing zone is safe and results in lower morbidity and mortality compared with the alternative of adjunctive visceral debranching or revascularization.^{13,14} The celiac axis can be plugged or coiled from a transfemoral or brachial approach to avoid endoleak after coverage. Additionally, even in those with preexisting superior mesenteric artery (SMA) stenosis, concurrent SMA stenting at the time of TEVAR has been shown to be safe and effective.⁶ In situations with poor collateralization between the celiac and SMA, the option for a celiac snorkel/chimney alongside the distal thoracic endograft has also become a popular option.

Although TEVAR with or without distal adjuncts to facilitate adequate seal has become the mainstay of aortic intervention for most aortic pathology confined to the descending thoracic aorta, it would be remiss not to address its increasing role in the treatment of patients with extended thoracoabdominal aneurysmal pathology as a less morbid option for care. In patients who are unfit for open repair, whether secondary to cardiac, pulmonary, renal disease, or prior thoracic surgery, using TEVAR proximally and extension distally into the paravisceral aorta by either hybrid or complete endovascular means have become attractive options. These distal extension techniques can be employed at the same time as proximal TEVAR or can be staged if extensive aortic coverage is required to reduce operative time and the risk of spinal cord ischemia. This latter option involves treating the descending thoracic aorta alone first, converting a type I to III thoracoabdominal aorta aneurysm (TAAA) to a type IV TAAA that could be treated later with either visceral debranching and extension of aortic coverage versus a fenestrated endograft or even an open type IV repair.

A hybrid approach for repair by way of visceral debranching followed by TEVAR extension has shown to be a good option for elderly high-risk patients.¹⁵ Although this option still requires a laparotomy for visceral revascularization, it avoids the need for an aortic cross-clamp and, in some cases, cardiopulmonary bypass. Furthermore, the visceral revascularizations are performed serially, and thus individual organ ischemic times are short. Additionally, if there is a concern for renal injury during the revascularization, the option to stage the two repairs during the same hospitalization in

anticipation of the need for contrast load during TEVAR has been shown to have excellent outcomes, with significantly fewer patients requiring mechanical ventilation and intensive care unit care postoperatively.^{15,16} Furthermore, staged repair in patients with the need for extensive aortic coverage may reduce the risk of spinal cord ischemia, allowing the patient to undergo full resuscitation and medical optimization after debranching before the endovascular procedure.¹⁵

Complete endovascular repair of the more extensive TAAAs (II-III), extending TEVAR coverage by using fenestrated EVAR in the paravisceral portion has emerged as an option with favorable mortality and morbidity rates, as well as acceptable spinal cord ischemia rates.¹⁷⁻²⁰ This option is limited by device availability and provider expertise in many lower-volume centers but has comparable outcomes to other treatment options and in some studies may even be associated with the lowest 30-day mortality compared with hybrid and open repair.²¹

SUMMARY

Finally, it should be noted that regardless of the adjunct maneuvers used to treat thoracic aortic pathology, long-term follow-up cannot be overemphasized. Although the main goal at the time of initial intervention is achieving an adequate seal to fully exclude an aneurysm or completely cover a dissection, one study suggests that up to 29% of patients will develop endoleaks after TEVAR, 11% of which were type Ia or Ib, over an 18-month mean follow-up due to progressive degeneration or stent migration.²² Initial 1-month CTA, followed by 6-month and then annual CTAs are crucial for adequate surveillance to catch these endoleaks early and prevent the risk of rupture. Fortunately, endovascular technology only continues to grow and evolve to enable less-invasive options for dealing with these complications. This allows patients who would not tolerate open repair, and thus may not have been candidates for surgery, to have the opportunity for treatment options with lower morbidity and mortality. However, it is important to recognize that as new techniques and technologies evolve, adequate long-term data will inherently lag, and thus it falls on the surgeon to individualize treatment to each patient to ensure the risks and benefits of options coincide with the status of the patient's overall health. ■

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